PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H02K 21/04, 21/20	A1	(11) International Publication Number: WO 99/09638 (43) International Publication Date: 25 February 1999 (25.02.99)

(21) International Application Number: PCT/US98/16841

(22) International Filing Date: 13 August 1998 (13.08.98)

(30) Priority Data:
08/910,436 13 August 1997 (13.08.97) US

(71) Applicant: ALLIEDSIGNAL INC. [US/US]; 101 Columbia Road, P.O. Box 2245, Morristown, NJ 07962-2245 (US).

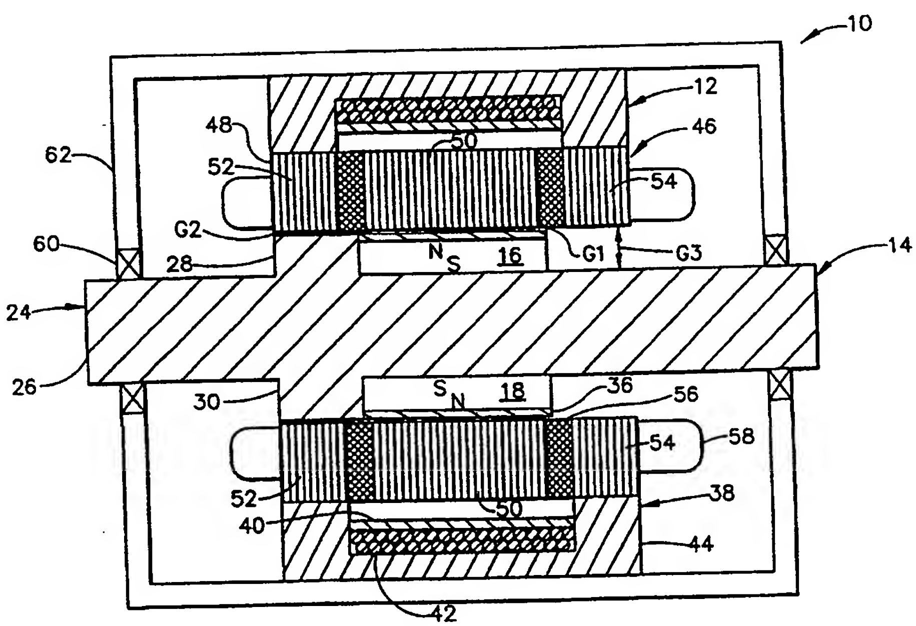
(72) Inventor: HUYNH, Co, Si; 913 East Maple Street, Glendale, CA 91205 (US).

(74) Agent: CRISS, Roger, H.; AlliedSignal Inc., Law Dept. (R. Fels), 101 Columbia Road, P.O. Box 2245, Morristown, NJ 07962-2245 (US).

(81) Designated States: JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: COMPACT HYBRID ELECTRICAL MACHINE



(57) Abstract

An electrical machine includes both a permanent magnet source of field excitation and an electromagnetic source of field excitation. The electrical machine also includes a homopolar rotor, which carries the permanent magnet source, and a lamination stack having a middle portion and outer portions. The homopolar rotor and the middle portion of the lamination stack conduct flux generated by the permanent magnet source. The homopolar rotor and the outer portions of the lamination stack conduct flux generated by the electromagnetic source when the electromagnetic source is energized.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

COMPACT HYBRID ELECTRICAL MACHINE

BACKGROUND OF THE INVENTION

The present invention relates to an electrical machine that utilizes both permanent magnets and an electromagnetic coil for field excitation. When such a hybrid electrical machine is operated as a generator, its output voltage can be bucked or boosted by varying the direction and amplitude of current flowing though the electromagnetic coil.

The hybrid electrical generator combines the ruggedness, light weight and compactness of a permanent magnet generator with the variable voltage capability of an inductor generator. Unlike a permanent magnet generator, the hybrid electrical generator does not require complex circuitry for regulating output voltage, and it does not require a parasitic load for dumping excess energy. The hybrid electrical generator is also smaller than an inductor generator designed for the same operating parameters.

However, the hybrid electrical generator is big and bulky in comparison to a permanent magnet generator designed for the same operating parameters. Size being important, a compact hybrid electrical generator is needed.

SUMMARY OF THE INVENTION

A compact electrical machine according to the present invention comprises a rotor assembly including a permanent magnet source of excitation, and a stator assembly including an electromagnetic source of excitation. The stator assembly further includes a flux collector having a middle portion for the permanent magnet source and first and second outer portions for the electromagnetic source. The middle portion is magnetically insulated from the outer portions.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional view of an electrical machine according to the present invention;

Figure 2 is an illustration of flux flowing in the electrical machine, the flux being generated by permanent magnets, which form a part of the electrical machine;

Figure 3 is an illustration of flux flowing in the electrical machine, the flux being generated by an electromagnet, which forms a part of the electrical machine; and

Figure 4 is a cross-sectional view of an alternative embodiment of the electrical machine.

DETAILED DESCRIPTION OF THE INVENTION

Figures 1, 2 and 3 show a hybrid electrical machine 10 including a stator assembly 12 and a rotor assembly 14. The rotor assembly 14 includes a first, second, third and fourth permanent magnets16, 18, 20, 22, which provide a first source of field excitation for the electrical machine 10. Figures 1 and 2 show the magnets 16, 18, 20, 22 being magnetized radially and arranged in a standard four-pole configuration. The permanent magnets 16, 18, 20, 22 can be made of ceramic or any other magnetic material. High-speed machines might utilize permanent magnets 16, 18, 20, 22 made of a magnetic material having a high energy product, such as a rare earth material.

The rotor assembly 14 also includes a homopolar rotor 24 made of a high-strength ferromagnetic material. The homopolar rotor 24 includes a shaft 26, which carries the permanent magnets 16, 18, 20, 22; a first pair of ferromagnetic pole pieces 28, 30 extending radially from the shaft 26 adjacent one side of the permanent magnets 16, 18, 20, 22; and a second pair of ferromagnetic pole pieces 32, 34 extending radially from the shaft 26 adjacent an opposite side of the permanent magnets 16, 18, 20, 22. The ferromagnetic pole pieces 28, 30 of the first pair are circumferentially offset by 90 mechanical degrees and 180

electrical degrees from the ferromagnetic pole pieces 32, 34 of the second pair to form North and South poles. The ferromagnetic pole pieces 28, 30 of the first pair are circumferentially aligned with the first and second permanent magnets 16, 18 (i.e., the North pole magnets), and the ferromagnetic pole pieces 32, 34 of the second pair are circumferentially aligned with the third and fourth permanent magnets 20, 22 (i.e., the South pole magnets). The homopolar rotor 24 can be machined from a single piece of a ferromagnetic material, whereby the shaft 26 and the pole pieces 28, 30, 32, 34 are integrally formed.

In high speed machines, the permanent magnets 16, 18, 20, 22 are retained by a retainer sleeve 36 made of a non-magnetic material such as a composite graphite. The retainer sleeve 36 is wound over the permanent magnets 16, 18, 20, 22. Gaps between the permanent magnets 16, 18, 20, 22 can be filled with a non-magnetic material such as an epoxy.

The permanent magnets 16, 18, 20, 22 and the retainer sleeve 36 are disposed entirely between the ferromagnetic pole pieces 28, 30, 32, 34. Outer diameters of the retainer sleeve 36 and the ferromagnetic pole pieces 28, 30, 32, 34 are substantially the same. Resulting is a compact rotor assembly 14.

The stator assembly 12 includes an electromagnet 38 operable to provide a second source of excitation for the electrical machine 10. The electromagnet 38 includes a bobbin 40 made of a non-magnetic material, a coil 42 wound around the bobbin 40, and a ferromagnetic yoke 44 to which the bobbin 42 is secured.

The stator assembly 12 also includes a flux collector 46 disposed between the rotor assembly 14 and the electromagnet 38. The flux collector 46 includes a lamination stack 48 having a middle portion 50 and first and second outer portions, 52, 54. Magnetic insulators 56 having the same shape as the laminations in the stack 48 are disposed between the middle portion 50 and the outer portions 52, 54. The magnetic insulators 56, which can be made of a non-metallic or plastic material, magnetically insulate the middle portion 50 from the outer portions 52, 54.

Stator windings 58 are wound around the middle and outer portions 50, 52, 54 of the lamination stack 48. The windings 58 can have a conventional configuration, such as a three-phase phase configuration. Resulting is a compact stator assembly 12.

The middle portion 50 of the lamination stack 48 is aligned with the permanent magnets 16, 18, 20, 22. Between the outer surface of the permanent magnets 16, 18, 20, 22 and the inner surface of the middle portion 50 is a first radial air gap G1 of low reluctance. The middle portion 50 and the shaft 26 provide a conductive path for flux from the permanent magnets 16, 18, 20, 22. The first outer portion 52 of the lamination 48 stack is aligned with the first pair of pole pieces 28, and the second outer portion 54 of the lamination 48 stack is aligned with the second pair of pole pieces 32, 34. Between the outer surfaces of the ferromagnetic pole pieces 28, 30, 32, 34 and the inner surface of the lamination stack 48 is a second air gap G2 of low reluctance. Between the outer surface of the shaft 26 and the inner surface of the laminations stack 48 is a third air gap G3 of high reluctance. The yoke 46, the outer portions 52, 54 of the lamination stack 48 and the homopolar rotor 24 provide a conductive circuit for the flux generated by the coil 42.

The rotor assembly 14 is supported by bearings 60 within a housing 62. The yoke 44 is secured to the housing 62, and the outer portions 52, 54 of the lamination stack 48 are secured to the yoke 44.

The electrical machine 10 is operated as an electrical generator by rotating the shaft 26, varying the amplitude and direction of current in the coil 42, and extracting electrical energy from the stator windings 58. While the shaft 26 is being rotated, flux from the first and second permanent magnets 16, 18 flows across the first air gap G1 to the middle portion 50 of the lamination stack 48, partially around the lamination stack 48, back across the first air gap G1, to the third and fourth permanent magnets 20, 22, through the shaft 26, and back to the first and second permanent magnets 16, 20 (see Figure 2). As the shaft 26 is rotated and flux from the permanent magnets 16, 18, 20, 22 cuts through the

stator windings 58, an ac voltage is induced in the stator windings 58.

When the coil 42 is energized, flux from the coil 42 flows from the yoke 46 to the first outer portion 52 of the lamination stack 48, across the second air gap G2, down the ferromagnetic poles 28, 30 of the first pair, to the shaft 26, across the shaft 26 to the pole pieces 32, 34 of the second pair, back across the second air gap G2, through the second outer portion 54 of the lamination stack 48, and back to the yoke 46 (see Figure 3). The magnetic insulators 56 prevent the coil flux from short-circuiting across the middle portion 50 of the lamination stack 48. As the flux from the coil 42 cuts through the stator windings 58, an additional ac voltage is induced in the stator windings 58.

The coil 42 can boost or buck the output voltage of the electrical machine 10. The amplitude and direction of the current energizing the coil 42 determines the amount of boost or buck. If current flowing in one direction causes the coil 42 to boost the output voltage of the electrical machine 10, then current flowing in an opposite direction will cause the coil 42 to buck the output voltage.

The electrical machine 10 could have an electromagnet 38 that is capable of generating the same voltage as the permanent magnets 16, 18, 20, 22. Operating such a machine without the electromagnet 38 produces an output voltage at 50% of the machine's maximum voltage. Varying the amplitude and direction of the current in the coil 42 can buck the output voltage of the electrical machine 10 to zero volts, boost the output voltage to the maximum voltage, or control the output voltage to a level between zero volts and the maximum voltage.

Thus disclosed is a hybrid electrical machine 10 that, when operated as an electrical generator, offers control over the output voltage without the need for complex, expensive, high power electronic circuitry. It does not require a parasitic load for dumping excess energy. Additionally, the electrical machine 10 has a small air gap G2 between the ferromagnetic pole pieces 28, 30, 32, 34 and the lamination stack 48, which results in a high flux density. Additionally, the hybrid electrical machine 10 is compact.

It is understood that changes and modifications can be made without departing from the spirit and scope of the present invention. For example, a rotor assembly 114 of a hybrid electrical machine 110 can include a homopolar rotor 124 having a multi-piece construction shown in Figure 5. The homopolar rotor 124 has a first shaft section 126a and a first pair of ferromagnetic pole pieces 128, 130 extending radially from the first section 126a; a second shaft section 126b and a second pair of ferromagnetic pole pieces 132, 134 extending radially from the second section 126b; and a third shaft section 126c for carrying permanent magnets 116, 118, 120, 122. The third and fourth permanent magnets 120, 122 and the pole pieces 132, 134 of the second pair. The multi-piece construction allows for easier fabrication and assembly of the rotor assembly 114. A permanent magnet rotor (i.e., the permanent magnets 116, 118, 120, 122, a retainer sleeve 136, and the third shaft section 126c) can be pre-assembled, and the pre-assembled rotor can then be clamped between the first and section shaft sections 126a, 126b by means such as a tie rod (not shown). Additionally, the retainer sleeve 136 can be shrink-fitted (instead of wound) over the permanent magnets 116, 118, 120, 122.

A specific electrical machine 10 is designed in accordance with its intended usage. Thus, the electrical machine 10 is not limited to the four-pole configuration and the lamination geometry shown in the drawings.

Dimensions of the electrical machine 10 are also determined in accordance with the intended usage. Overall axial length and diameter of the electrical machine 10 is determined by factors such as its desired power rating. The homopolar rotor 24 is sized to handle flux from the electromagnet 38 and the permanent magnets 16, 18, 20, 22 without saturating. The relative sizes and strengths of the electromagnet 38 and permanent magnets 16, 18, 20, 22, and the relative lengths of the middle 50 and outer portions 52, 54 of the lamination stack 48 depend upon the desired amount of control over the output voltage. An electrical machine 10 having less control (e.g., ±10%) of the output voltage will have a relatively smaller electromagnet 38 and pole pieces than an electrical

machine having the same power rating but having total control over the output voltage.

Finally, the electrical machine 10 can be operated as a motor. Conventional motor circuitry such as inverters and sensors can supply an excitation to the stator windings 58. The amplitude of the field excitation can be controlled either by the electromagnet 38 or the conventional motor circuitry.

COMPACT HYBRID ELECTRICAL MACHINE

I CLAIM:

1. An electrical machine (10) comprising:

a rotor assembly (14) including a permanent magnet source of excitation(16, 18, 20, 22); and

a stator assembly (12) including an electromagnetic source of excitation (38), and a flux collector (46) having a middle portion (50) for the permanent magnet source (16, 18, 20, 22) and first and second outer portions (52, 54) for the electromagnetic source (38), the middle portion (50) being magnetically insulated from the outer portions (52, 54).

2. The electrical machine (10) of claim 1, wherein the rotor assembly (14) further includes a homopolar rotor (24), the permanent magnet source (16, 18, 20, 22) being carried by the homopolar rotor (24) in alignment with the middle portion (50) of the flux collector (46), the middle portion (50) of the flux collector (46) and the homopolar rotor (24) conducting flux generated by the permanent magnet source (16, 18, 20, 22), the homopolar rotor (24) and the outer portions (52, 54) of the flux collector (46) conducting flux generated by the electromagnetic source (38) when the electromagnetic source (38) is energized.

3. The electrical machine (10) of claim 2, wherein the homopolar rotor (24) includes a shaft (26), a first group of ferromagnetic pole pieces (28, 30) extending radially from the shaft (26) in alignment with the first outer portion (52) of the flux collector (46); and a second group of ferromagnetic pole pieces (32, 34) extending radially from the shaft (26) in alignment with the second outer portion (54) of the flux collector (46).

4. The electrical machine (10) of claim 3, wherein the rotor assembly (14) further includes a retainer sleeve (36) for the permanent magnet source (16, 18, 20, 22), the retainer sleeve (36) and the ferromagnetic pole pieces (28, 30, 32, 34) having substantially the same outer diameters.

5. The electrical machine (10) of claim 1, wherein the electromagnet includes:

a bobbin (40) surrounding the flux collector (46);

a coil (42) wound around the bobbin (40); and

a ferromagnetic yoke (44) for conducting flux from the coil (42) to the outer portions (52, 54) of the flux collector (46) when the coil (42) is energized.

6. The electrical machine (10) of claim 1, wherein the flux collector (46) includes a lamination stack (48) and insulators (56) for magnetically insulating the middle portion (50) of the lamination stack (48) from the outer portions (52, 54) of the lamination stack (48).

The electrical machine (10) of claim 6, wherein the stator assembly (12) further includes stator windings (58) wound around the middle and outer portions (50, 52, 54) of the lamination stack (48).

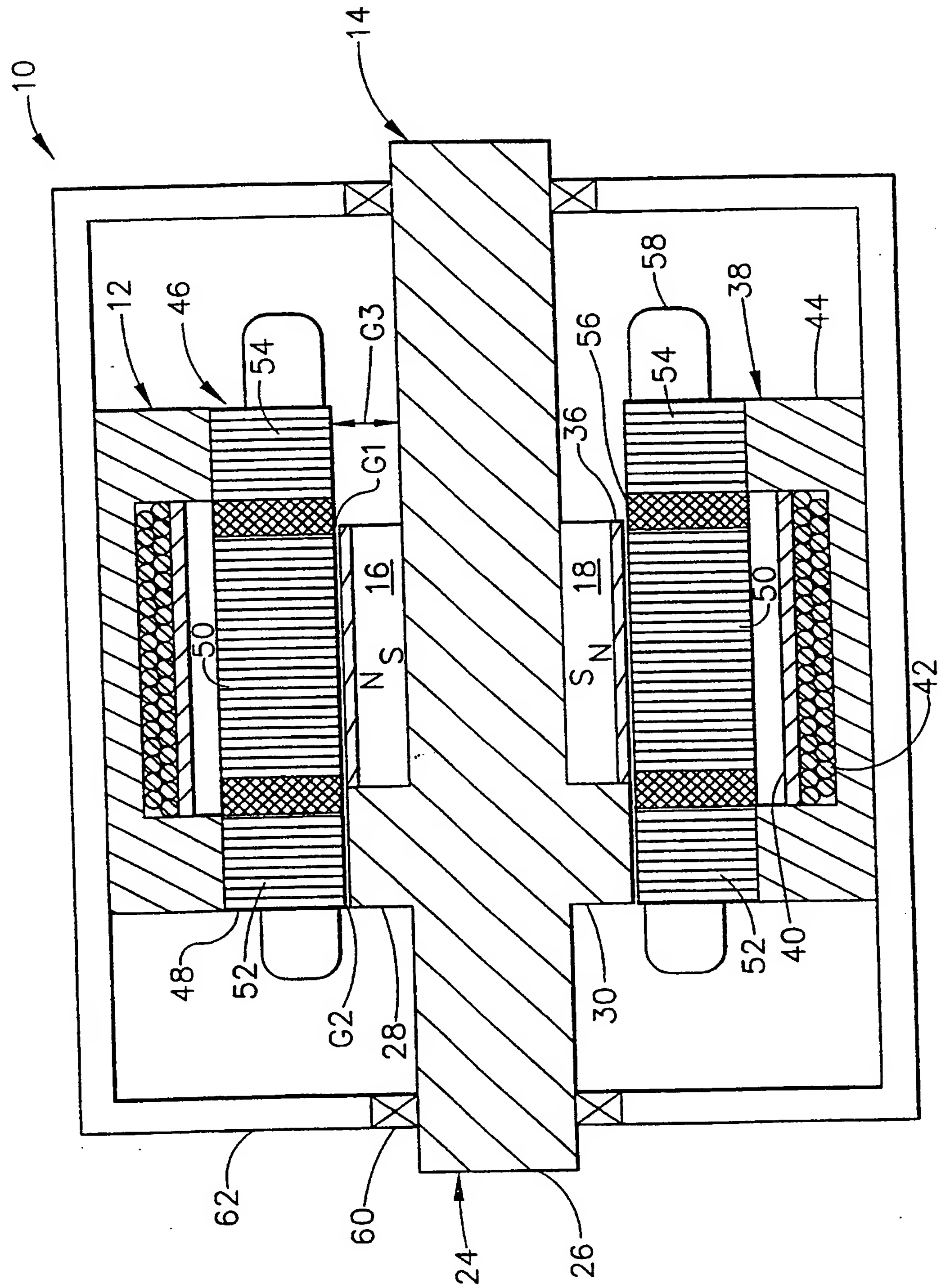

10
14
12
46
54
G3
G1
58
38
44
56
36
54
16
N
S
18
S
N
50
50
42
48
52
G2
28
30
52
40
62
60
24
26

FIG. 1

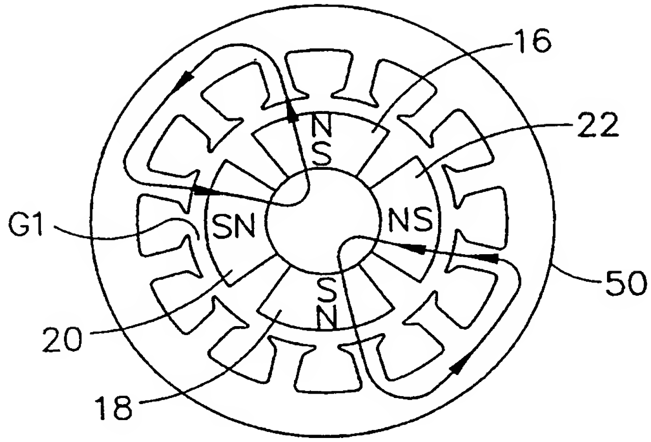


FIG. 2

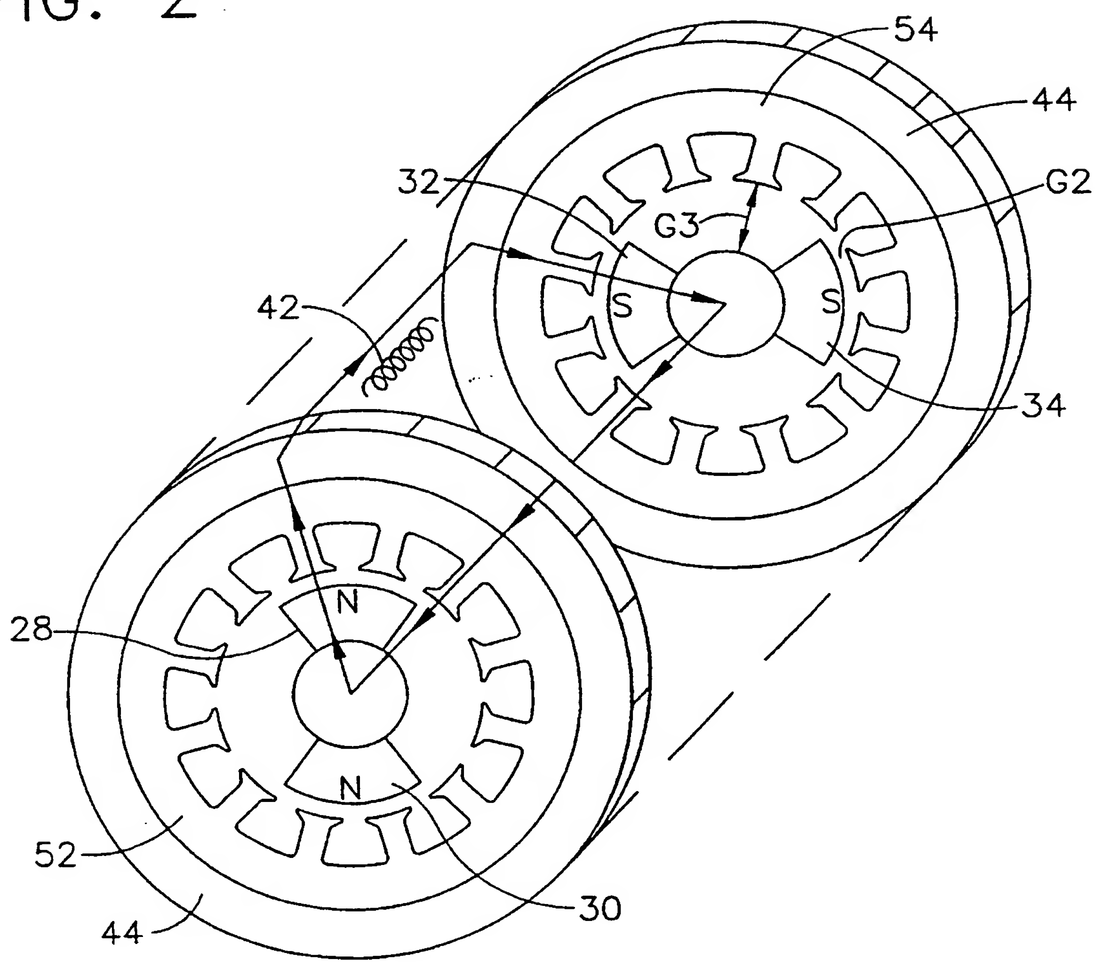


FIG. 3

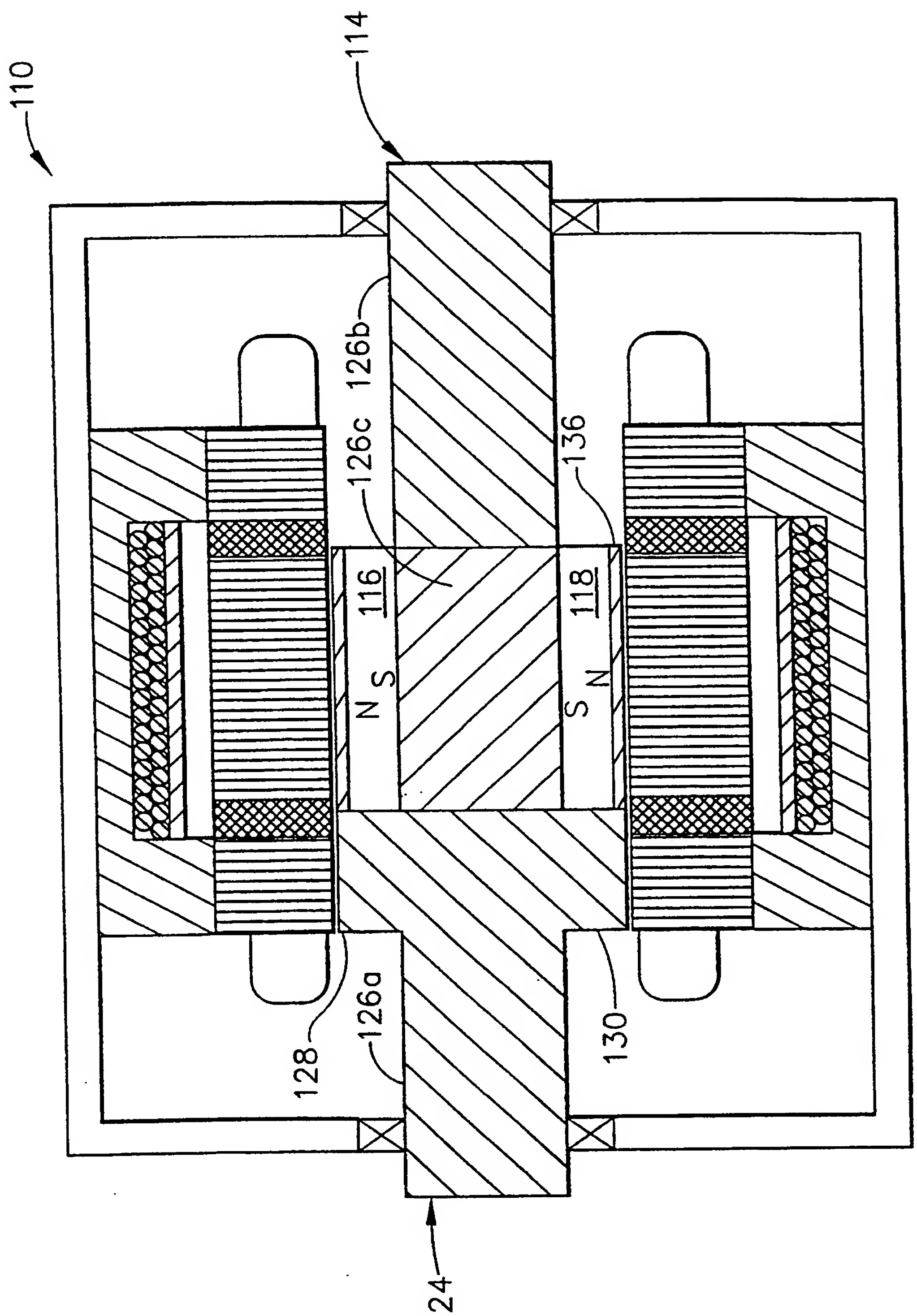


FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/16841

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H02K21/04 H02K21/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 504 382 A (DOUGLASS MICHAEL J ET AL) 2 April 1996	
A	US 4 782 257 A (SECHER BERNARD ET AL) 1 November 1988	
A	US 5 317 227 A (PALMA RODOLFO ET AL) 31 May 1994	
A	US 4 385 251 A (MALLICK JOHN A ET AL) 24 May 1983	
A	US 3 614 496 A (SCHIETHART LODEWIJK) 19 October 1971	

[ ] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 November 1998	03/12/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Ramos, H

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 98/16841

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5504382 A	02-04-1996	NONE	
US 4782257 A	01-11-1988	FR 2572229 A	25-04-1986
		EP 0183576 A	04-06-1986
US 5317227 A	31-05-1994	AU 4640693 A	04-07-1994
		CA 2148688 A	23-06-1994
		EP 0673558 A	27-09-1995
		JP 8503358 T	09-04-1996
		WO 9414225 A	23-06-1994
US 4385251 A	24-05-1983	NONE	
US 3614496 A	19-10-1971	NL 6900864 A	21-07-1970
		BE 744465 A	15-06-1970
		CH 518644 A	31-01-1972
		DE 1940128 A	13-08-1970
		FR 2032317 A	27-11-1970
		GB 1286035 A	16-08-1972
		IE 33692 B	02-10-1974